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HEAT CONDUCTIVITY DETECTOR

[001] This is a Continuation of International Application PCT/DE02/01488, with an international filing date of April 23, 2002, which was published under PCT Article 21(2) in German, and the disclosure of which is incorporated into this application by reference.

FIELD OF AND BACKGROUND OF THE INVENTION

[002] Thermal conductivity detectors are used to detect certain liquid or gaseous substances (fluids) on the basis of their characteristic thermal conductivity, particularly in gas chromatography. For this purpose, the substances to be detected, after their chromatographic separation, are successively guided past an electrically heated heating filament disposed in a channel. Depending on the thermal conductivity of the substance flowing past, more or less heat is diverted from the heating filament to the channel wall, and the heating filament is correspondingly cooled to a greater or lesser degree. As a result of the cooling of the heating filament, its electrical resistance changes, which is detected. For this purpose, the heating filament is typically disposed in a measuring bridge, which contains additional resistors and an additional heating filament in a further channel through which a reference fluid flows.

[003] To detect very small amounts of substances with great sensitivity and accuracy requires a correspondingly small structure of the thermal conductivity detector. Micromechanical production methods are particularly suitable for this purpose. Due to the small overall size, however, special problems are encountered. For example, the heating filament, which is under tension at an ambient temperature, may relax as a result of its thermal expansion at operating temperatures ranging from 100°C to

200°C and above. The relaxed filament may then cause the fluid flowing through the channel to then induce vibrations in the heating filament, which increase the detector noise of the thermal conductivity detector and thereby decrease the detection limit. These vibrations may also cause premature fracturing of the very thin heating filament.

OBJECTS OF THE INVENTION

[004] Accordingly, one object of the invention is to provide an improved thermal conductivity detector. Another object is to provide a thermal conductivity detector that reduces or eliminates the particular problems addressed above.

SUMMARY OF THE INVENTION

[005] According to one formulation of the invention, these and other objects are addressed by a thermal conductivity detector with an electrically heatable heating filament that is mounted in a central region of the channel, such that the fluid can flow around it. To this end, it is mounted at its two ends on two electrically conductive carriers intersecting the channel. At least one of the two carriers is configured in such a way that its distance from the other carrier is greater in the region of the channel center than in the region of the channel wall.

[006] This special configuration of at least one carrier, preferably both carriers, causes the center regions of the two carriers on which the heating filament is mounted by its two ends to move away from one another as the temperature increases and thereby to tighten the heating filament. Thus, the heating filament advantageously remains in the center of the channel, so that the measuring characteristics of the thermal conductivity detector do not change.

[007] The relaxation of the heating filament as the temperature increases is counteracted particularly effectively if the at least one carrier is at least approximately V-shaped in its region that intersects the channel.

[008] To achieve the greatest possible thermal expansion in the at least one carrier in order to tighten the heating filament, the corresponding carrier is preferably made exclusively of metal. In other words, the carrier is not fabricated from a carrier substrate made of a material with low thermal expansion, such as silicon dioxide, to which a conductive film is applied.

[009] It is very difficult in practice to compensate completely the heat-related longitudinal expansion of the heating filament by the thermal expansion of the carriers, even if configured according to the invention. The unheated heating filament is therefore preferably held under sufficient tension between the two carriers so that the heating filament is still subject to some tension even when operating temperatures are reached. This would not be possible with carriers that are not configured according to the invention because the tension of the unheated heating filament would have to be set so high that the heating filament would break, or it would have to be made more stable and thus thicker.

[010] Particularly in view of a micromechanical production of the thermal conductivity detector according to the invention, the carriers holding the heating filament are preferably formed on a carrier plate that is provided with a groove. The channel is formed by this groove and an additional groove made in a cover plate that is placed on the carrier plate.

BRIEF DESCRIPTION OF THE DRAWINGS

[011] The invention will now be described in greater detail, by way of example, with reference to an embodiment of the thermal conductivity detector according to the invention, as depicted in the figures, in which:

FIG 1 is a longitudinal section (I-I') of the thermal conductivity detector, and

FIG 2 shows the same thermal conductivity detector in cross section (II-II').

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[012] A carrier plate 1 with a groove 2 is covered by a cover plate 3 with an additional groove 4, such that the two grooves 2 and 4 together form a channel 5. The channel 5 preferably has a circular cross section. A heating filament 6 extends longitudinally along the center of the channel 5. The filament 6 is held at its two ends on two electrically conductive carriers 7 and 8, which intersect the channel 5. Each of the two carriers 7 and 8 is configured in such a way that its distance from the respective other carrier in the region of the center of the channel 5, i.e., where the heating filament 6 is mounted, is greater than in the region of the channel wall 9. To this end, the two carriers 7 and 8 are substantially V-shaped here, in their areas intersecting the channel 5, such that the two sides of each V-shaped carrier 7 and 8 extend at an approximately 45° angle to the channel wall 9.

[013] In its unheated state the heating filament 6 is held between the carriers 7 and 8 at a predefined tension. To heat the heating filament 6, an electric current is applied via the two carriers 7 and 8. The reduced tension resulting from the heat-related longitudinal expansion of the heating filament 6 is partly compensated because the central areas of the two carriers 7 and 8 on which the heating filament 6 is mounted move away from one another as the temperature increases, so as to tighten the heating

filament 6 (see dashed lines). The tension of the unheated filament 6 is adjusted such that the heating filament 6 is still under a tension ≥ 0 at operating temperatures, i.e., in the range of 100°C to 200°C. In other words, it preferably does not become slack. However, the preset tension value of the unheated heating filament 6 can be lower by the amount of the compensation of the tension reduction. For example, if the tension reduction of the heated heating filament 6 is compensated by 40%, only the remaining 60% would need to be compensated when the tension of the unheated heating filament 6 is adjusted.

[014]

In this preferred embodiment, for the micromechanical production of the thermal conductivity detector, the carrier plate 1 is initially made of a silicon substrate 10, which carries an insulating layer 11 of silicon dioxide on one side. Metal layers are subsequently applied to this insulating layer 11, (e.g., titanium, chromium, platinum, gold), which on the one hand (gold and/or platinum) subsequently form the carriers 7 and 8 and the heating filament 6 and, on the other hand, act as a bonding agent (titanium, chromium) or a reinforcement (gold) of the layers. In etching processes, the carriers 7 and 8 and the heating filament 6 are formed by structuring the metal layers, and the groove 2 is made in the carrier plate 1. When the carriers 7 and 8 are formed, the insulating layer 11 as the substrate for the carriers 7 and 8 is eliminated as far as possible, such that the carriers consist only of metal and thus can freely expand when heated. Finally, the carrier plate 1 and the cover plate 3 are joined, such that the grooves 2 and 4 that have been made therein form the channel 5. The channel diameter is approximately 0.15 mm, the length of the heating filament is approximately 1 mm and the diameter of the heating filament is $< 1 \mu\text{m}$.

[015]

The above description of the preferred embodiments has been given by way of example. From the disclosure given, those skilled in the art will not only understand

the present invention and its attendant advantages, but will also find apparent various changes and modifications to the structures and methods disclosed. It is sought, therefore, to cover all such changes and modifications as fall within the spirit and scope of the invention, as defined by the appended claims, and equivalents thereof.